Patent Application of

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For

ON TIME STEAM QUALITY, TEMPERATURE, AND PRESSURE MEASURING METHOD AND APPARATUS AT THE HEAD OF AN INJECTION WELL

FIELD OF INVENTION

The present invention relates to on-line monitoring, opto-electric technology, and optics of the fiber sensors. Widespread applications pertaining to the extraction of dense oil and the geothermal energy, within an oil refinery or inside a turbo generator will be afforded by this said method; heavy-duty machinery utilizing steam as a power source will also benefit.

BACKGROUND OF THE INVENTION

The initial steam injection method, invented during the 1970s, currently continues application in the extraction of dense oil. In further explanation, the steam utilized is the production of the boiler; temperature and pressure levels do not usually exceed 360℃

(680 ^{0}F) and 20 Mpa, respectively. Steam quality is equalized by admixing water located at the wellhead; temperature and pressure levels will fluctuate. If the applied steam quality exceeds normalcy, many negative consequences occur; oil layer breakdown, flow misdirection, and a decrease in output. In reverse, if the steam quality dips below a median level, flow ease of the dense oil will become difficult. Hence that therefore, the steam quality utilized must be monitored at all points in time. An optimal state of the extraction process is achievable by controlling steam quality.

The current existing method to determine steam quality requires a separator, transported by a machinery truck. Once the truck situates onto the working site, the fluid mixture consisting of steam and water is linked into the separator, which will break down the mixture into two individual phases. By measuring velocity, temperature and pressure of each of the two phases, steam quality can be extrapolated; the two individual phases will be combined into an original single state and is replaced into the well. The particular said separator does not possess capabilities to control the flow of two individual phases nor measure distances; problems occur such as errors and a low accuracy level. Coinciding, the aforementioned process of separating and re-combining the said liquids is not reversible. Closely examined, the named "separated single phases" reveal that the mixed state remains, whether it is water with steam or steam with water. Proven from use, the separator is not capable measuring zero steam quality (i.e. all is water), or all steam quality (i.e. all is steam). Further yet, the method in practice is not competent to distinguish to distinguish dissolving steam in water.

SUMMARY OF THE INVENTION

The present invention is intelligent enough to overcome any shortfalls presented by the current separator; long-range measurement is achievable as well. On the basis of the invented apparatus three data collection methods are options, first hand accumulation at the work site, long-range (transmittable by cable), and by means of a satellite controlled indoors. The invented apparatus maintains a compact structure, installed on a long-term basis at the wellhead; analytical data is obtainable at any point in time.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be best understood by way of the following description of a method employing the principles of the invention as illustrated in the accompanying drawings, in which:

Figure 1 shows a structure diagram of the sensor of steam quality.

Figure 2 displays the overall structure of the present invention.

REFERENCE NUMERALS IN DRAWING

1. Sensor stand of optical fiber
2. Red copper washer
3. Heat-resistant stainless steel pipe
4. Optical fiber sensor
   - 4(a). Steam quality sensor
   - 4(b). Pressure sensor
   - 4(c). Temperature sensor
5. Sealing washer
6. Stand for pressure transition
7. Standard Flange plate
8. Screw
9. Heat insulation washer
10. Heat reflected pipe
11. Radiator
12. Block end

13. Screw
14. Silicon rubber washer
15. Connective stand with heat insulation
16. Screw
17. Box of circuit plate
18. Convective radiator
19. Circuit plate
20. End cover
21. Supporting frame of plug
22. Cable plug
23. Cable
24. Transducer
25. Plug of computer notebook
26. Circuit transmitting joint for long-range control
27. Glass fiber-stuffing
28. Opto-electric transfer joint
29. Optical fiber
30. Stainless steel pipe
31. Nut
32. Lead washer
33. Sealing stand
34. Red copper washer
35. Probe of optical fiber

Figure 3 represents a block diagram of the circuit. The three signals obtained ρ, t, and p, are converted into stable simulated signals by the steps of opto-electric transfer and linear correction. The above-mentioned piece is to be installed into the upper portion of the circuit plate, then will be connected to a transducer by means of a cable. Included in the transducer is a circuit of the micro-processing unit; this unit will transmit the signal of steam/water ratio via A/D transfer as a finale.

The installation sketch diagram in the working site is displayed in Figure 4. In further detail, many of the sensors, as a bulk, are installed onto the injection pipe. The transducer, installed into a junction box, maintains a power supply of 110v/220v at the work site location; furthermore, connected to a cable possessing a long-range data collection, transmission of controlled signals in a long-range are possible. An additional

function of the transducer is to command four electro-magnetic values located on the steam pipe and separate executive device.

DETAILED DESCRIPTION

The present invention pertains to a method and an apparatus for monitoring of steam quality, temperature, and pressure on-line. Steam quality can be defined as

$$\rho \;= \text{Quality of steam / quality of water + quality of steam.}$$

In a dynamic condition, steam quality depends on temperature, pressure, and the velocity of steam inside a specified pipe. At this time, the dynamic equation of the two-phase flow is under construction. The quality of steam and its correlating change is expressed by a curve; composed from several data points collected by instantaneous measurements. Measuring the space refractive index of steam/water combined fluid by utilizing sensors of the optical fiber is the main principle of the invented method. It is assumed that the refractive index of water is 1.33, and steam 1.0. For a single phase, either water or steam in a pipe, refractive index fluctuations are not sensitive to the coordinating temperature and pressure; however steam is compressible. Fluctuations in density, pressure, and the refractive index can be neglected when gas remains in the flow condition. Also, it is known that the space refractive index of water/steam mixture does not correlate sensitivity towards temperature and pressure regarding the fluid inside a pipe; therefore the index is capable of representing the steam/water ratio of the analyzed object. Given, the value of the index n_2 is $1 \le n_2 \le 1.33$ ($n_2 = 1$, all is steam; $n_2 = 1.33$, all is water).

Figure 1 displays the structure diagram of the steam quality **4(a)** sensor. Light produced from the opto-electric transfer **28** transmits to the probe **35**, which then comes into contact with an analyzed fluid, through an optical fiber. In a case where the incident

angle of light θ_1 is less than the refractive angle of light θ_2 [$\theta_2 = \sin^{-1}(n_2/n_1)$], transmissivity of the said incident light, arbitrarily polarized, is expressed as the following

$$T = \frac{n_2 \cos\theta_2}{n_1 \cos\theta 1}\left\{\left[\frac{2\sin\theta_2\cos\theta_1}{\sin(\theta_2+\theta_1)\cos(\theta_2-\theta_1)}\right]+\left[\frac{2\sin\theta_2\cos\theta_1}{\sin(\theta_1+\theta_2)}\right]\right\}$$

Where n_1 represents the refractive index of the probe, n_2 represents the space refractive index of steam/water-combined fluid θ_1 represents the incident angle of light, and θ_2 represents the refractive angle. In field use, the probe is constructed of blue gem; the tip of the gem's surface portrays a half-circular shape. The light reflected from the end of the probe R will be expressed as $R£«T \approx 1$. As an additional step, the light reflected will enter into the opto-electric transfer **28**; light is transformed into an electric signal, the aforementioned is now represented by the expression of the steam/water combined ratio. The wick/cover ratio of the optical fiber **29** is precisely 300 μm/ 420 μm. Installed together inside the stainless steel pipe, are two of the optical fibers; high temperature resistant glue is utilized to seal the said fibers jointly. The fragment of the optical fiber residing inside the pipe will be inserted into the sealing stand **33**; the nut **31** is tightened together with the lead washer **32**. At this point, the sealing stand **33** is installed into the sensor's stand **1** by employing a red copper washer, detailed in Figure 2.

Similar structure characteristics of the pressure sensor **4(b)** can be identified with that of the steam quality sensor. A diaphragm, located at the front end of the sensor gaps of 0.5 ~ 2 mm from the optical fiber; when pressure is encountered, the gap is decreases. By determining the strength of the light transmitted, the corresponding pressure is known. Currently, the pressure sensor is widely accepted and available.

Referring to the temperature sensor, it is composed of quartz capillaries; the capillary walls are brushed with aluminum or gold film, possessing highly reflective properties. The determining temperature of the sensor fluctuates between room temperature and 400℃, widely accepted and available as well.

Installed onto the sensor stand 1 are the said sensors **4(a)**, **4(b)**, and **4(c)**. Figure 2 displays a detailed drawing of the structure regarding the present invention's sensor; two sections exist: the cable **23** connects a transducer and a bulk of sensors, all. Four blocks compose the bulk of sensors. N0.1 ~ 6 represents the high temperature block, directly entering the steam pipe; sealed by a Flange plate **7**. N0. 8 ~ 14 represents the temperature reducing block; the radiator **11** component possesses heat-emitting slots, constructed of stainless steel, the same as reflected pipe 10. N0.15 represents the heat insulation block, i.e. the third block of the body. The above-mentioned block is constructed of polytetrafluoroethane (PFE), and glass fibers throughout the center to prevent heat from emitting. The final fourth block of the bulk, N0.16 ~ 20, includes opto-electric transfer and the circuit plate. Pipes, **17** and **18** are constructed of stainless steel; the periphery on both ends of pipe **18** possesses ventilating slots to reduce temperature by method of convection. The circuit plate **19** connects to the transducer by a cable **23**; supported by the frame of plug **21** and the cable plug **22**. The transducer **24** transmits steam quality temperature and pressure signals to a long-range control room throughout the circuit-transmitting joint **26**. Included on one side of the transducer is a plug **25** utilized by the computer storage base, releasing data to the working site.

Figure 3 represents the block diagram of the circuit. The three signals obtained from the fiber optical sensors, ρ, t, and p transmit to the transducer by means of a

cable; methods of opto-electric transfer, amplification, and linear correction are applied. Once the above-mentioned steps occur, the digital signals, ρ, t, and p are accessible in the transducer via A/D transfer coinciding with the micro-processing unit. The following power sources, 24 V_{DC} or 12 V_{DC} utilized by the transducer, and 110v/220v, alternating, feeding to the junction box are readily available to the system as a whole. The present invention is capable of collecting the parameters of fluid inside the steam pipe and transmitting data to a long-range control room to be treated; based on the technology of steam injection.

Figure 4 displays the installation sketch diagram to be utilized at the working site. Located at the head of each injection well is a steam pipe; composed of two separate sets of three-way pipes. In further detail, when data collection occurs, the signal, received from the long-range control room, is capable of directing the four electromagnetic valves located on the steam pipe. Electrical signals are transformed into digital signals, once obtained from the transducer of the system; a two-phase fluid, consisting of water and steam, flows throughout the invented apparatus before the above said step occurs. To release data the transducer connects to the computer notebook. If the operator is not present at the working site, signals will be automatically transferred to the long-range control room. As previously mentioned, the parameters of ρ, t, and p at each injection well at any desired moment, and pre-treated signals, are obtainable in the form of computer feedback, applied at the working site. The computer system's software depends upon oil extraction technology. Installed inside the junction box, are several transducers; assists the corresponding injection well to produce results individually or simultaneously.

The water/gas two-phase flow liquid is complex in structure. Within a horizontal pipe, two simplified states can exist: mixed and layer-separated. In the layer-separated state, water stations bottom side, and gas rises to the top. Upon entrance into a vertical injection well, a mixed state will become of the layer-separated. The space refractive index is capable of being measured in either said states or any necessary time. The obtained gas/water ratio, at a particular extraction moment, does not pertain to the phase status.With having stated the above, it is noted that the density of steam, however, relates to corresponding temperature and pressure; neglect is possible to occur. Assuming the light produced from the sensor head of the steam quality possesses a visual angle of 160^{o}, and known is the occupied volume of steam and water, the steam quality value obtained at the extraction moment will be utilized as sole data.

From field practice, the present invention provides verifiable proof of capabilities to withstand and endure high temperature and pressure atmospheres all while providing accurate data; collection at the working site or long-range is possible. Another option is to receive data by satellite; a data emitting system will be an addition. Overall, the system error produced by the invented method is less than 3%.